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(54) METHOD AND APPARATUS FOR CONTINUOUS COATING

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B05D 5/00 (2006.01)
B05D 5/06 (2006.01)

(52) **U.S. Cl.**
USPC **427/256**; 427/64

(58) **Field of Classification Search** 427/64
See application file for complete search history.

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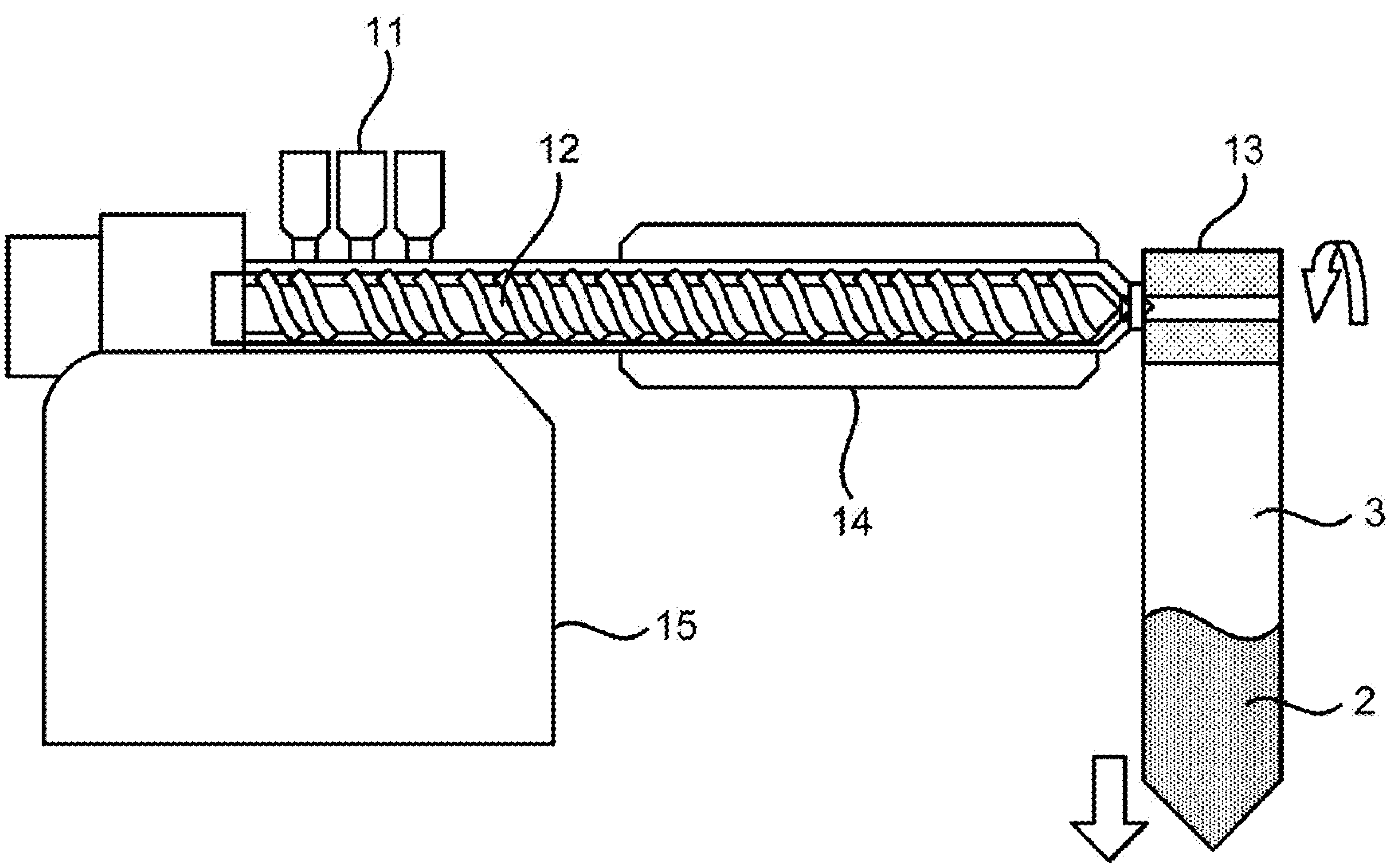
(57) **ABSTRACT**

Disclosed is a method and apparatus for continuous coating with a rotational die in which coating materials flow in a radial direction. The linear speed of a substrate in need of coating is identical to the tangential speed of the surface of the rotational die so that the coating material, which flows in a radial direction of the rotational die, flows onto the substrate perpendicularly. Therefore, the ingredients of coating materials overlap one another (or stand vertically as a layer), and the vertical sequence of the coating material is ensured. This method and apparatus can be used to make organic electronic devices, organic light-emitting diodes and organic photovoltaic devices. Particularly, this method and apparatus can be used in bulk-hetero-junction of mixed coating of P-type and N-type semiconductors.

15 Claims, 7 Drawing Sheets



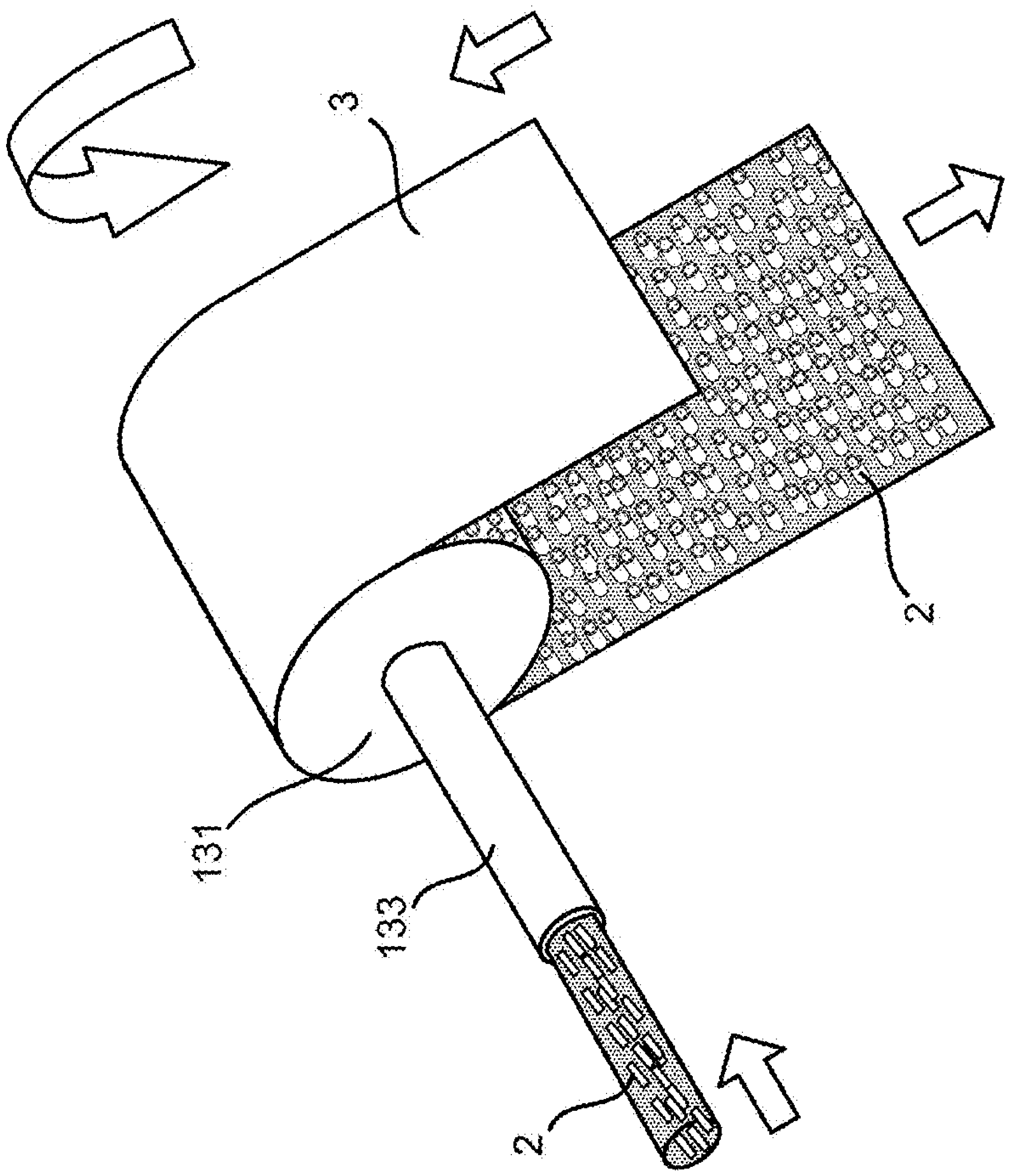


FIG. 1

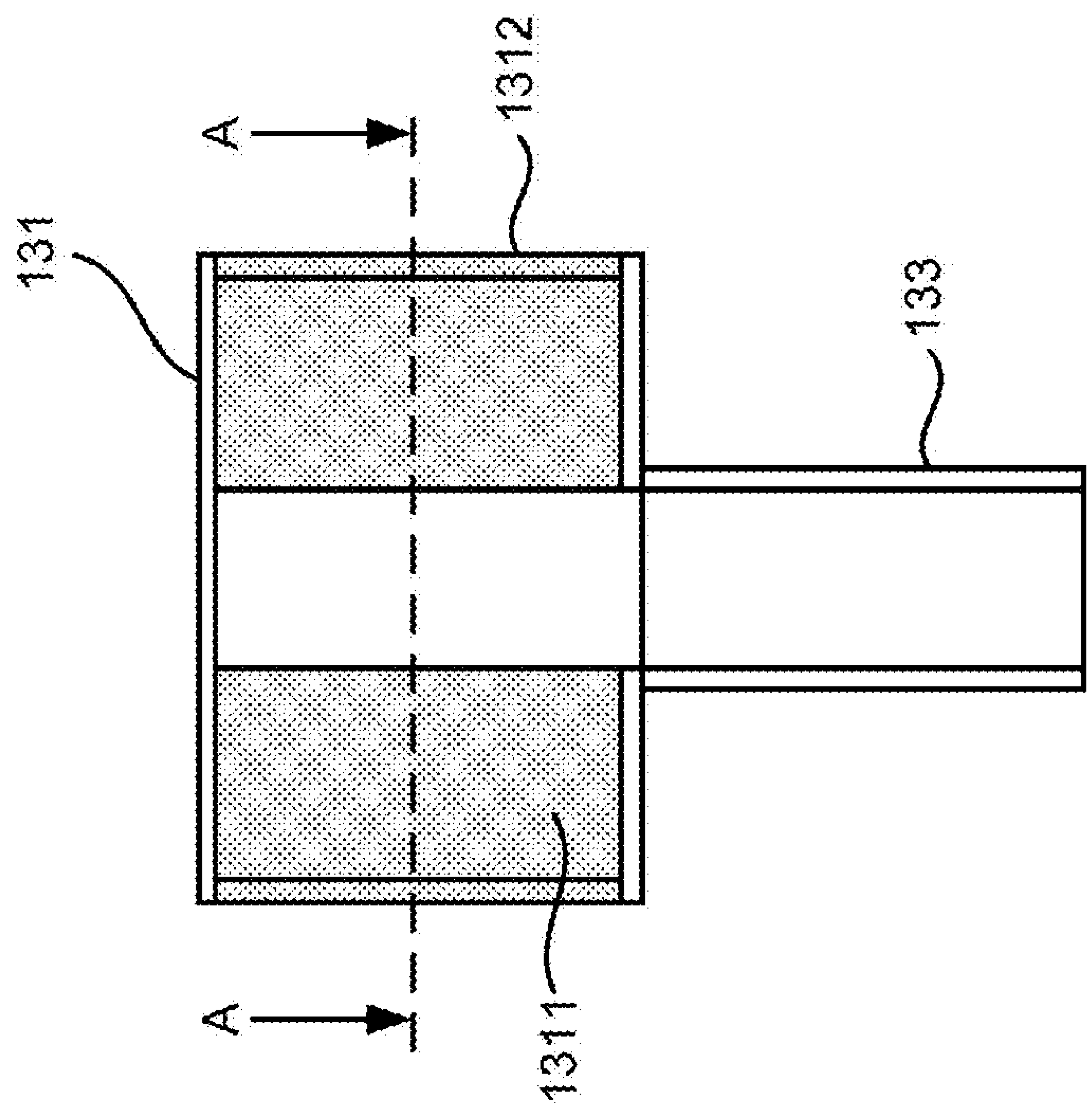


FIG. 2

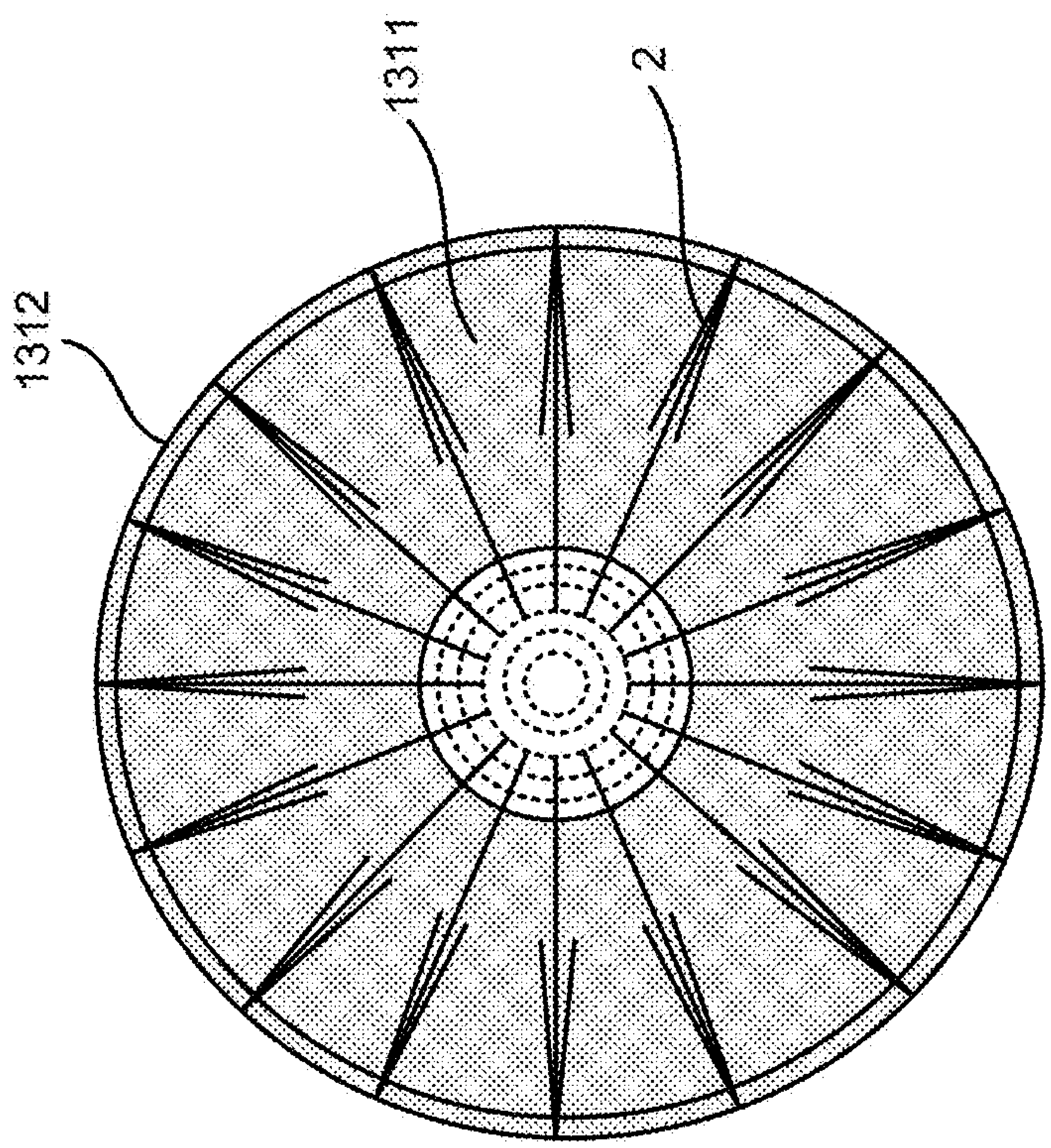


FIG. 3

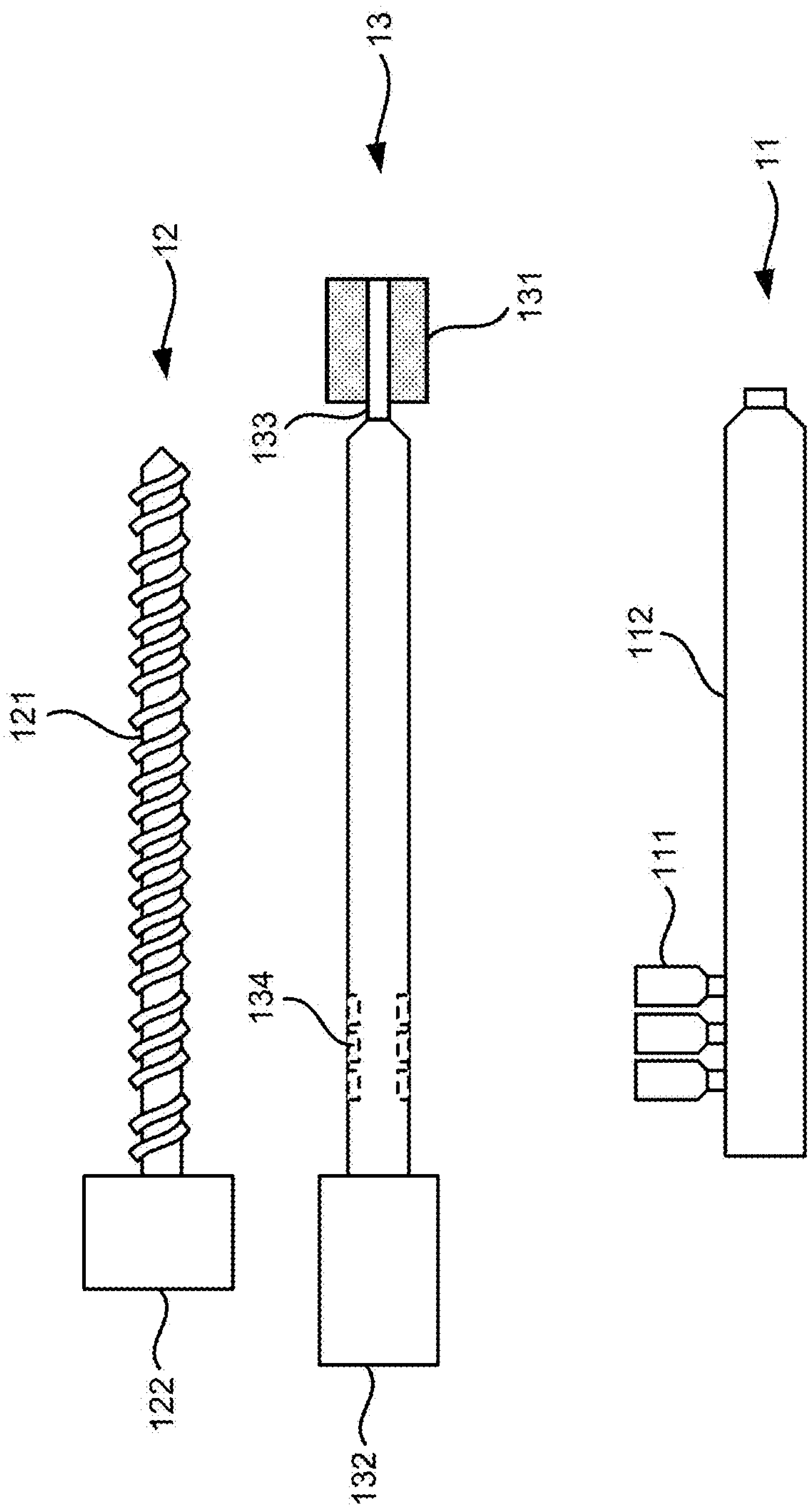


FIG. 4

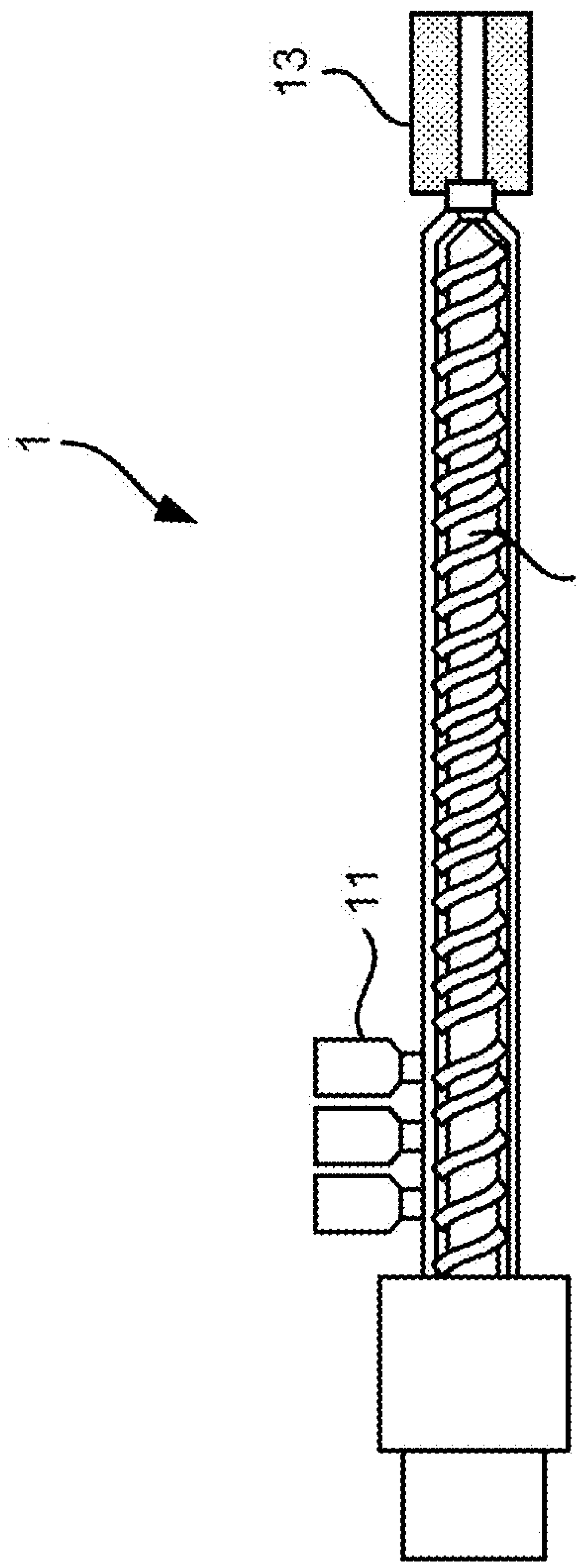


FIG. 5

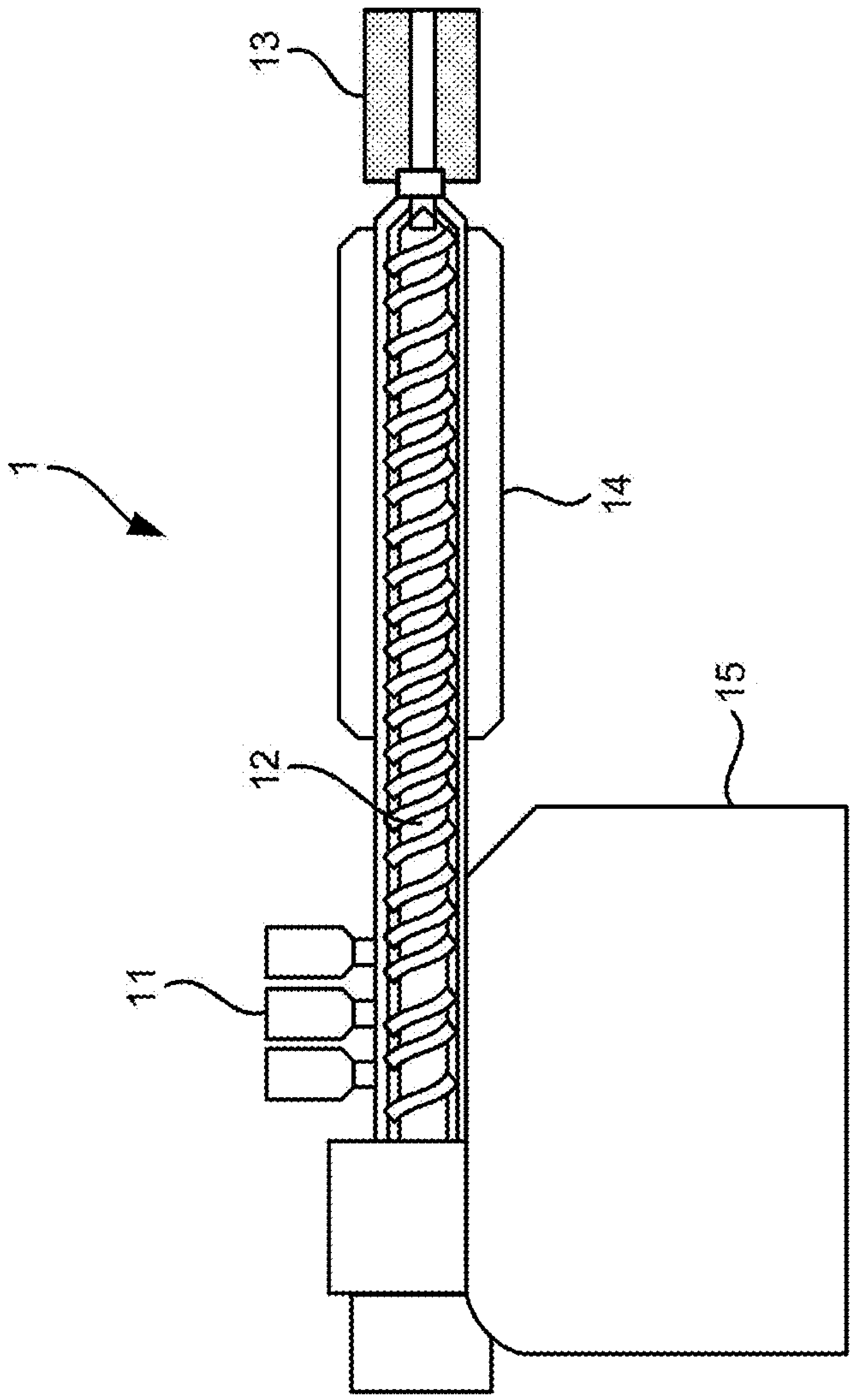


FIG. 6

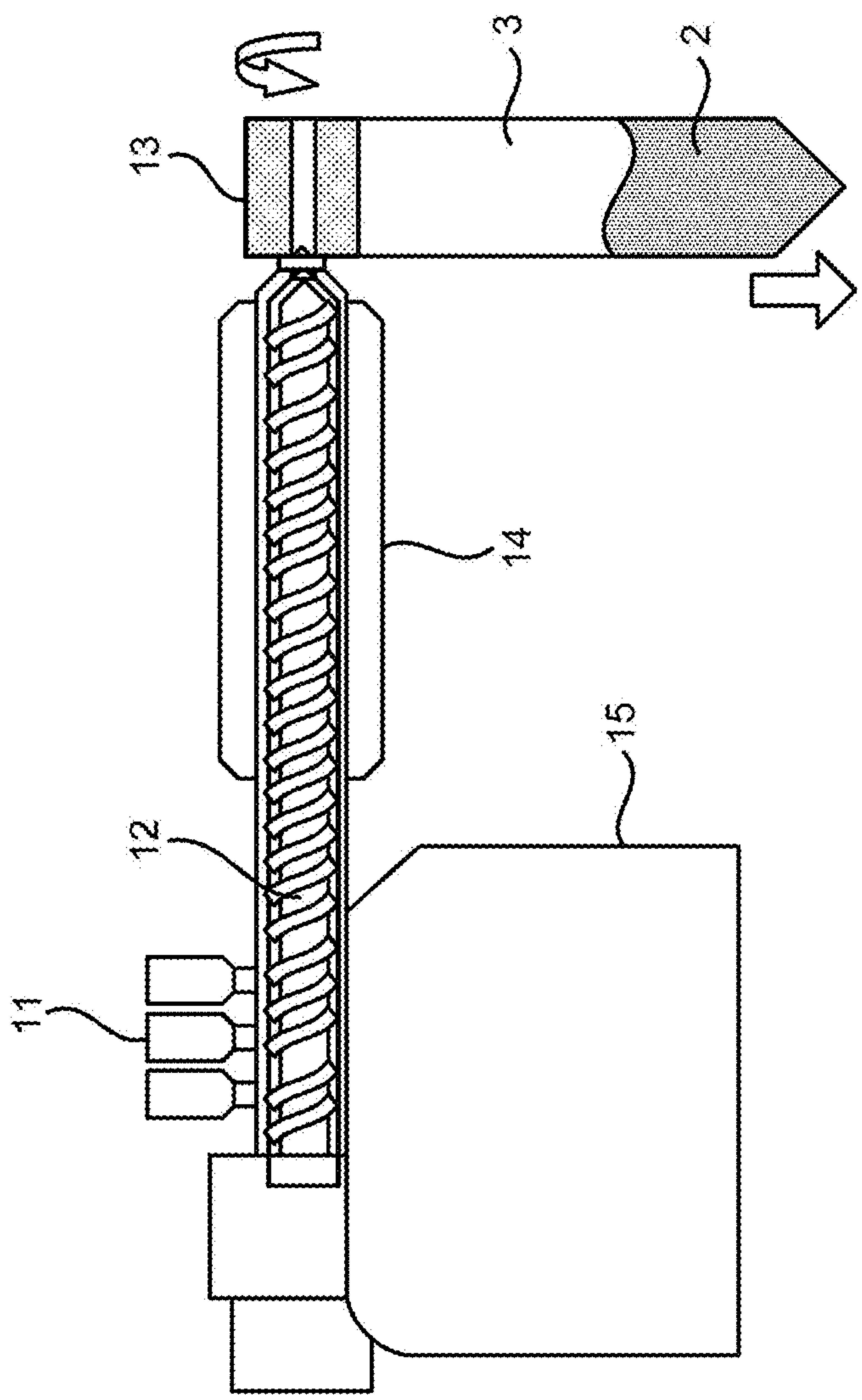


FIG. 7

METHOD AND APPARATUS FOR CONTINUOUS COATING

FIELD OF THE INVENTION

The present invention relates to a method and apparatus for continuous coating with a rotational die and, more particularly, to a method and apparatus for continuously, perpendicularly providing coating materials onto a substrate in need of coating so that the coating materials are in order vertically.

DESCRIPTION OF THE RELATED ARTS

There are conventional methods for coating such as brush painting, spray coating, screen-blade printing, screen-roll printing, ink-jet printing, roll coating, doctor-blade coating, dip coating, spin coating and slot die coating. A common objective of the conventional methods is uniformity of coating. The directional property of coating materials is seldom addressed. Almost nothing has been discussed about the vertical sequence of the coating materials on a substrate in need of coating. In making a layer (or multiple layers) of an organic electronic device with P-N junctions and, more particularly, in providing a layer (or layers) of bulk-hetero junctions of mixed coating of P-type and N-type organic semiconductors for solar cell, the mixed P-type and N-type organic semiconductor coating elements are better provided in order vertically (i.e. perpendicular to the flat-substrate of being coated) for preventing loss, while transmitting electrons and holes, due to un-effective inner recycling of P-N junctions. The conventional methods however cannot satisfy this need.

The direction of movement of a brush is parallel to the direction of coating in the brush painting. The direction of movement of a blade is parallel to the direction of coating in the screen-blade method or blade method. The direction of spin of drops of coating materials is parallel to the direction of coating in the spin coating. The direction of movement of a slot die is parallel to the direction of coating in the slot-die coating. Therefore, the coating materials are provided in parallel to the direction of relative movement.

In the ink-jet printing, droplets reach the substrate perpendicularly. The droplets however tend to form spheres because of cohesion. The droplets splash and spread horizontally on the substrate because they reach the substrate at high speed. The spray coating shares the same problems with the ink-jet printing.

In the roll coating and the screen-roll printing, the coating materials are provided onto a roll from a barrel in all directions. Therefore, the coating materials are not provided onto the substrate perpendicularly.

The present invention is therefore intended to obviate or at least alleviate the problems encountered in prior art.

SUMMARY OF THE INVENTION

It is the primary objective of the present invention to provide a method for coating materials, one at a time, onto a substrate perpendicularly so that the coating materials are in order vertically.

To achieve the foregoing objective, the method includes the step of providing an input device for transmitting at least one ingredient of each of the coating materials into the shell. There is provided a rotational die for receiving each of the coating materials from the input device. Each of the coating materials travels in a radial direction in the rotational die. The rotational die is driven so that the tangential speed on the periphery of the rotational die is identical to the linear speed

of the substrate, thus providing each of the coating materials onto the substrate perpendicularly. An area of the substrate for receiving each of the coating materials from the rotational die is 1% to 99% of the entire area of the periphery of the rotational die.

Other objectives, advantages and features of the present invention will become apparent from the following description referring to the attached drawings.

BRIEF DESCRIPTIONS OF THE DRAWINGS

The present invention will be described via detailed illustration of the preferred embodiment referring to the drawings.

FIG. **1** is a perspective, partial view of a coating apparatus according to the preferred embodiment of the present invention.

FIG. **2** is a cross-sectional, partial view of the coating apparatus shown in FIG. **1**.

FIG. **3** is a cross-sectional, partial view of the coating apparatus shown in FIG. **2**.

FIG. **4** is an exploded, partial view of the coating apparatus shown in FIG. **1**.

FIG. **5** is a cross-sectional, partial view of the coating apparatus shown in FIG. **4**.

FIG. **6** is cross-sectional view of the coating apparatus of FIG. **1**.

FIG. **7** is a cross-sectional view of a substrate in need of coating with the coating apparatus shown in FIG. **6**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. **6** and **7**, there is shown an apparatus **1** for coating a substrate according to the preferred embodiment of the present invention. The coating apparatus **1** includes an input device **11**, an extrusion device **12**, a rotational die assembly **13**, a temperature control device **14** and a supportive device **15**.

Referring to FIGS. **4** and **5**, the input device **11** includes a shell **112** and at least one barrel **111** in communication with shell **112**. There are three barrels **111** for examples. Each of the barrels **11** is used to contain an ingredient of a coating material. Each of the ingredients is fed into the shell **112** from a related one of the barrels **111**.

The rotational die assembly **13** includes a rotational die **131**, a tube **133** in communication with the rotational die **131** and a motor **132** connected to the tube **133** so that the motor **132** drives the rotational die **131** through the tube **133**. The tube **133** is inserted in the shell **112**. The tube **133** includes apertures **134** defined therein. The materials are fed into the tube **133** from the shell **112** through the apertures **134**. The diameter and number of the apertures are determined based on the rate of the feed of the ingredients of the coating material. The internal diameter of the tube **133** may be constant or changing throughout the length of the tube **133**.

Referring to FIGS. **2** and **3**, the rotational die **131** includes a core **1311** and a peripheral layer **1312** provided around the core **1311**. The core **1311** is made of a porous material, a solid material in which tunnels are made, a sintering metal, a sintered ceramic material, sintered glass, a woven material, a non-woven material or any combination of the above-mentioned materials. The micro-structure of the core **1311** must be uniform so that the coating material leaves the periphery of the rotational die **131** evenly and vertically.

The peripheral layer **1312** may be made of a material identical to or different from that of the core **1311**. Where the peripheral layer **1312** and the core **1311** are made of different materials, they are made separately and then connected to each other. Where the peripheral layer **1312** and the core **1311** are made of one same material identical, they are preferably made in one piece. The peripheral layer **1312** may be formed with a pattern for dividing the coating material into various regions on the substrate **3**.

The extrusion device **12** includes a screw **121** and a motor **122** operatively connected to the screw **121** so that the motor **122** rotates the screw **121**. The screw **121** is inserted in the cylinder **112**. The screw **121** mixes and transmits the gradients of the coating material. The diameter and pitch of the screw **121** may be constant or changing throughout the length of the screw **121**. There is only one screw **121** in the preferred embodiment. However, there may be two screws arranged in a series or one in another in another embodiment. The screw **121** may be replaced with a positive pushing device used to make polymers in another embodiment.

The screw **121** and an internal side of the tube **133** are considered together in order to provide desired mixing and transmitting. For example, a thread may be formed on the internal side of the tube **133** to provide excellent mixing.

Referring to FIG. **7**, the substrate **3** is provided around the rotational die **1311**. The substrate **3** can be reeled and expanded. A spacer may be used to keep the substrate **3** from the peripheral layer **1311** by a gap. However, a force may be used to bring the substrate **3** into contact with the peripheral layer **1311** if so desired. An area of the substrate **3** for receiving each of the coating materials from the peripheral layer **1311** is 1% to 99% of the entire area of the peripheral layer **1311**. The ratio is preferably 5% to 99%. More preferably, the ratio is 10% to 99%. More preferably, the ratio is 40% to 99%. More preferably, the ratio is 50% to 99%. This ratio can be adjusted by providing two rollers to push the substrate **3** onto the spacer or peripheral layer **1311**.

Each of the coating materials travels in a radial direction in the rotational die **131** because of the screw **121**. The travel of each of the coating materials may alternatively be caused by a positive pushing force or pressure in the tube **133** or vacuum around the rotational die **131**.

The motor **132** rotates the rotational die **131** via the tube **133** so that the tangential speed of any point of the peripheral layer **1311** is identical to the linear speed of the substrate **3** so that each of the coating materials perpendicularly reaches the substrate **3** from the peripheral layer **1311**. Each of the coating materials may be left on the substrate **3** because of adhesion. Alternatively, a force may be used to leave each of the coating materials on the substrate **3**. The force is exerted with a blade or a current of fluid. The fluid may be gas form or liquid. The gas may be air, nitrogen, inert gas, solution and organic dissolvent.

The substrate **3** is moved past the rotational die **131** several so that all of the coating materials are provided onto the substrate **3** from the rotational die **131**, one over another. Thus, the coating materials are in order vertically.

The method can advantageously be used to make an electronic device selected such as an organic electronic device, an organic light-emitting diode and an organic photovoltaic device. The method can be used to provide organic polymer onto the substrate **3**. The organic polymer may be directional liquid crystal. The method can advantageously be used for bulk-hetero junction in mixed coating of P-type and N-type organic semiconductors.

The present invention has been described via the detailed illustration of the preferred embodiment. Those skilled in the art can derive variations from the preferred embodiment without departing from the scope of the present invention. Therefore, the preferred embodiment shall not limit the scope of the present invention defined in the claims.

What is claimed is:

1. A method for providing coating materials, one at a time, onto a substrate perpendicularly so that the coating materials are in order vertically, comprising the steps of:

providing an input device for transmitting at least one ingredient of each of the coating materials into an extrusion device;

providing a rotational die for receiving each of the coating materials from the input device and the extrusion device, wherein each of the coating materials travels in a radial direction in the rotational die; and

rotating the rotational die so that the tangential speed on the periphery of the rotational die is identical to the linear speed of the substrate, thus providing each of the coating materials onto the substrate perpendicularly so as to make an electronic device selected from a group consisting of an organic electronic device, an organic light-emitting diode, and an organic photovoltaic device;

wherein an area of the substrate for receiving each of the coating materials from the rotational die is 1% to 99% of the entire area of the periphery of the rotational die.

2. The method according to claim **1**, wherein each of the coating materials travels in a radial direction in the rotational die because of at least one force selected from a group consisting of extrusion with a screw, a positive pushing force, pressure in the extrusion device, and vacuum around the rotational die.

3. The method according to claim **1**, wherein the substrate is reeled and expanded.

4. The method according to claim **1**, wherein each of the coating materials is left on the substrate because of adhesion.

5. The method according to claim **1** comprising the step of providing a force to leave each of the coating materials on the substrate, wherein the force is exerted in a manner selected from a group consisting of cutting with a blade and blowing with fluid.

6. The method according to claim **5**, wherein the fluid comprises at least one material selected from a group consisting air, nitrogen, inert gas, solution and organic dissolvent.

7. The method according to claim **1**, wherein ratio of the area of the substrate for receiving each of the coating materials from the rotational die to the entire area of the periphery of the rotational die is in a range selected from a group consisting of 5% to 99%, 10% to 99%, 40% to 99% and 50% to 99%.

8. The method according to claim **1**, wherein the method is used for bulk-hetero junction in mixed coating of P-type and N-type organic semiconductors.

9. A method for providing coating materials, one at a time, onto a substrate perpendicularly so that the coating materials are in order vertically, comprising the steps of:

providing an input device for transmitting at least one ingredient of each of the coating materials into an extrusion device;

providing a rotational die for receiving each of the coating materials from the input device and the extrusion device, wherein each of the coating materials travels in a radial direction in the rotational die; and

rotating the rotational die so that the tangential speed on the periphery of the rotational die is identical to the linear speed of the substrate, thus providing each of the coating materials onto the substrate perpendicularly so as to provide organic polymer onto the substrate, wherein the organic polymer is directional liquid crystal;

wherein an area of the substrate for receiving each of the coating materials from the rotational die is 1% to 99% of the entire area of the periphery of the rotational die.

10. The method according to claim **9**, wherein each of the coating materials travels in a radial direction in the rotational die because of at least one force selected from a group consisting of extrusion with a screw, a positive pushing force, pressure in the extrusion device, and vacuum around the rotational die.

11. The method according to claim **9**, wherein the substrate is reeled and expanded.

12. The method according to claim **9**, wherein each of the coating materials is left on the substrate because of adhesion.

13. The method according to claim **9** comprising the step of providing a force to leave each of the coating materials on the substrate, wherein the force is exerted in a manner selected from a group consisting of cutting with a blade and blowing with fluid.

14. The method according to claim **13**, wherein the fluid comprises at least one material selected from a group consisting air, nitrogen, inert gas, solution and organic dissolvent.

15. The method according to claim **9**, wherein ratio of the area of the substrate for receiving each of the coating materials from the rotational die to the entire area of the periphery of the rotational die is in a range selected from a group consisting of 5% to 99%, 10% to 99%, 40% to 99% and 50% to 99%.

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